VI. BLUE CRAB

Trend analyses on different 20-mm size groups in bag seine and trawl data (Figures 15, 16) for blue crab (Callinectes sapidus) showed that the smallest size classes increased in numbers, whereas the largest size classes decreased linearly. Though growth overfishing is the most probable cause of the decline in large crab, the trends may also have been affected by poorly-understood ecological changes such as increased predation and spatial shifts in habitat.

Trends in size-age groups

Blue crab are caught in substantial numbers throughout the year. Consequently all months were considered for trend analysis. Sample sizes were large enough that it was possible to subdivide the entire size range caught by bag seine and trawl into 20-mm size classes and perform trend analyses on them separately. Bag seine data showed a decline only in the largest size class of crab (>125 mm total carapace width, TW) while smaller size classes increased or showed no trend, a pattern compatible with a directed (growth) overfishing hypothesis (Figure 15). In contrast, trawl data showed declines in intermediate size classes as small as the 46-65 mm group, though the decline was greatest for the market-size groups (Figure 16). The legal size limit for blue crab is five inches TW (127 mm), but there is anecdotal evidence for considerable illegal harvesting of undersized crab. "Market size" crab were considered to be all those greater than 115 mm TW.

The intriguing differences in pattern for bag seine and trawl results possibly reflect differing conditions in bay margin (bag seine) and mid-bay (trawl) habitats. This suggests intermediate-size crab may be making increased use of the bay margin in preference to the open bay. However, confining the bag seine data to the years 1982-91 (the same years as for trawl data and years of densest sampling) resulted in essentially the same pattern of trends for both data sets, suggesting the differences may be the result of examining two time series of different lengths.

Recruitment was not a problem. The smallest size classes sampled by both bag seine and trawl showed increases (Figures 15A, B, C and 16A). If megalopal blue crab are as widely dispersed and mobile off the Texas coast as they are in other parts of the Gulf of Mexico (Steele and Perry 1990), strong recruitment could continue even if the adult population in that bay were reduced.

Geographic extent and trends by sex

Considerable variation may be ascribed to local conditions. Drop-sampler data from a salt marsh in Galveston Island State Park showed opposite trends from those found here for bag seine (McTigue and Zimmerman, pers. comm.). Trawl data subdivided by bay zone (upper and lower estuary) yielded trends differing in shape and magnitude, but not in direction of slope, implying the overall declines are bay-wide rather than local

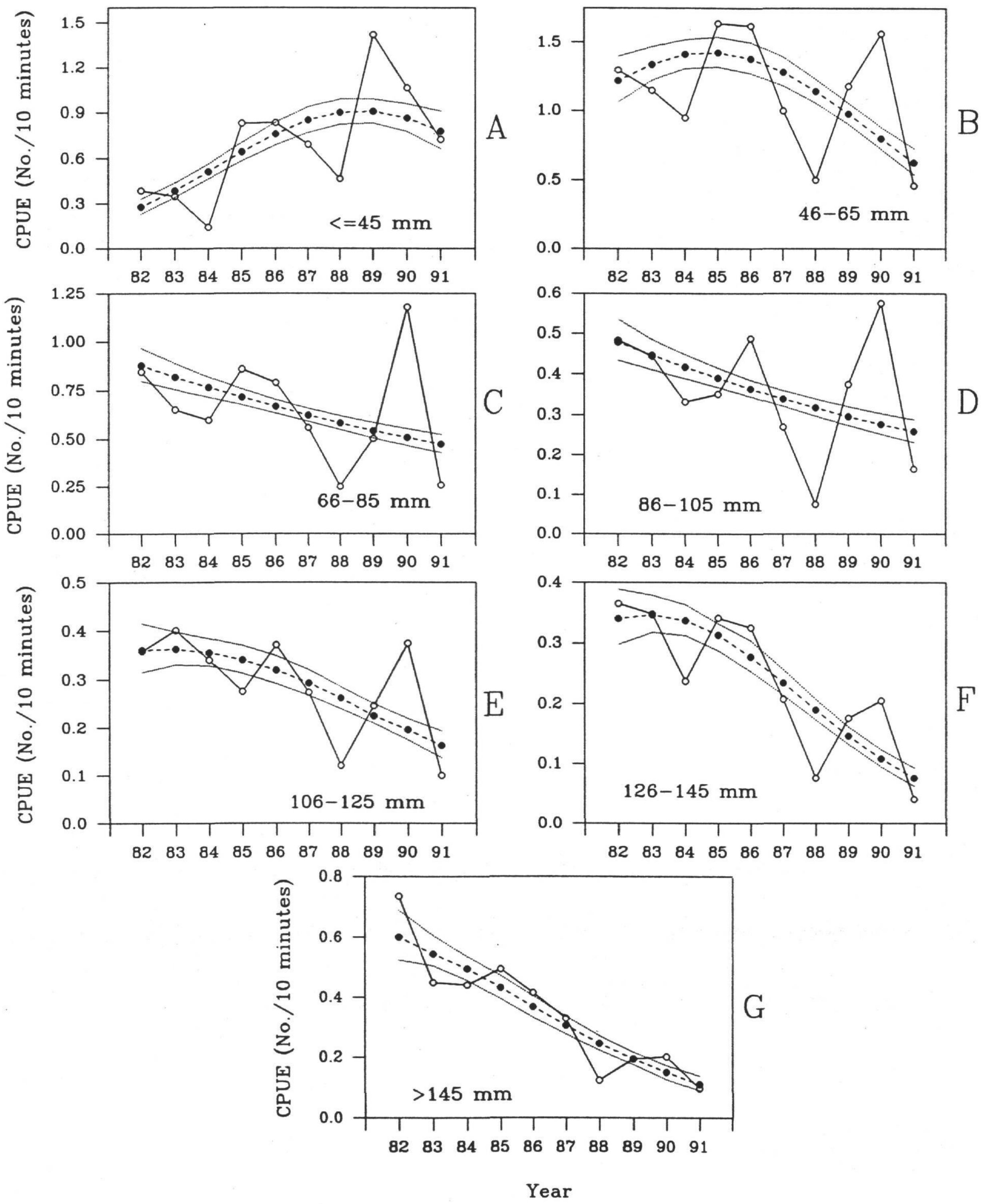


Figure 16. Mean annual CPUE with fitted values and confidence intervals (±S.E.) for seven size classes of blue crab caught by trawl.

phenomena (Figure 17). There were greater slopes and a quadratic component to the trends in the upper bay (oligohaline-mesohaline), while the lower bay (mesohaline-polyhaline) showed gentler, linear trends.

The greater intensity of the decline in large crab in the upper bay zone raised the possibility of directed overfishing of male blue crab (Figure 17C). Female crabs are obliged to migrate to high-salinity waters in order to spawn but males are not (More 1969, Benefield and Linton 1990). Consequently males tend to concentrate in the fresher parts of estuaries where they are targeted by the fishery (Millikin and Williams 1984, McClintock and Marion 1990). Females outnumber males in the CF data set, especially in trawl samples. Sampling bias is also a possibility if adult male crab are concentrated far upriver and high in freshwater areas, where neither bag seine nor trawl samples are taken. Analyses of deviance revealed no significant differences in trends between males and females that would demonstrate directed overfishing of males. The available time series is short, however, because sex data were only recorded from 1982 through 1987. Neither are there obvious differences in the spatial distribution of the two sexes at any time of year that cannot be explained by a greater number of females in the data set (Figures 18, 19, 20).

More crab are landed from the Galveston Estuary than any other in Texas (Hammerschmidt 1985). Because the Galveston Estuary is the largest in Texas, calculations of coastwide trends, weighted by estuarine area, revealed a coastwide decline in the size of blue crab that influenced the Blue Crab Management Plan (Cody et al. 1992). However, a comparison of trends among all Texas estuaries (Figures 21, 22) showed analogous declines in the larger sizes of blue crab only in Aransas Bay (Figure 22D) and the Upper Laguna Madre (Figure 22F). These estuaries are sufficiently different from Galveston, both physically and economically, that the population trends of concern here should be considered unique to the Galveston Estuary.

Though recruitment was apparently strong in the Galveston Estuary, Figures 21-22 suggest there may be cause for concern in San Antonio Bay or the Laguna Madre.

Temporal extent and reliability

How long blue crab have been declining is unknown because a historical fishery-independent data set (previous to 1977) for blue crab is not available. The CF data indicate the observed trends have prevailed at least since 1978 or 1979 (Figure 15).

It is possible that the observed trends are merely the downward portion of a cyclical pattern, or that (as discussed for white shrimp) a real decline may be superimposed on natural population cycles. The discussion here continues on the assumption that the trends are affected by human activity.

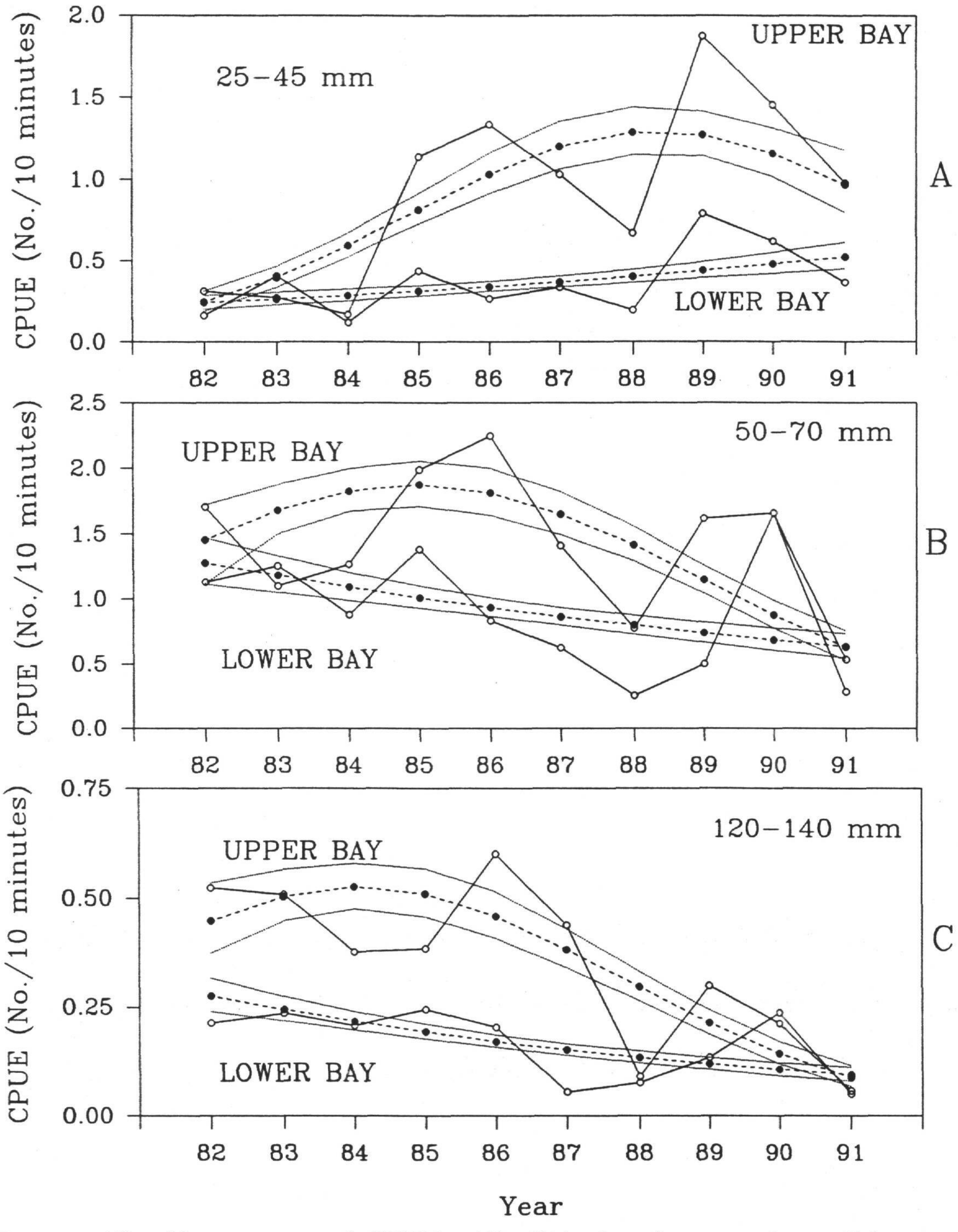
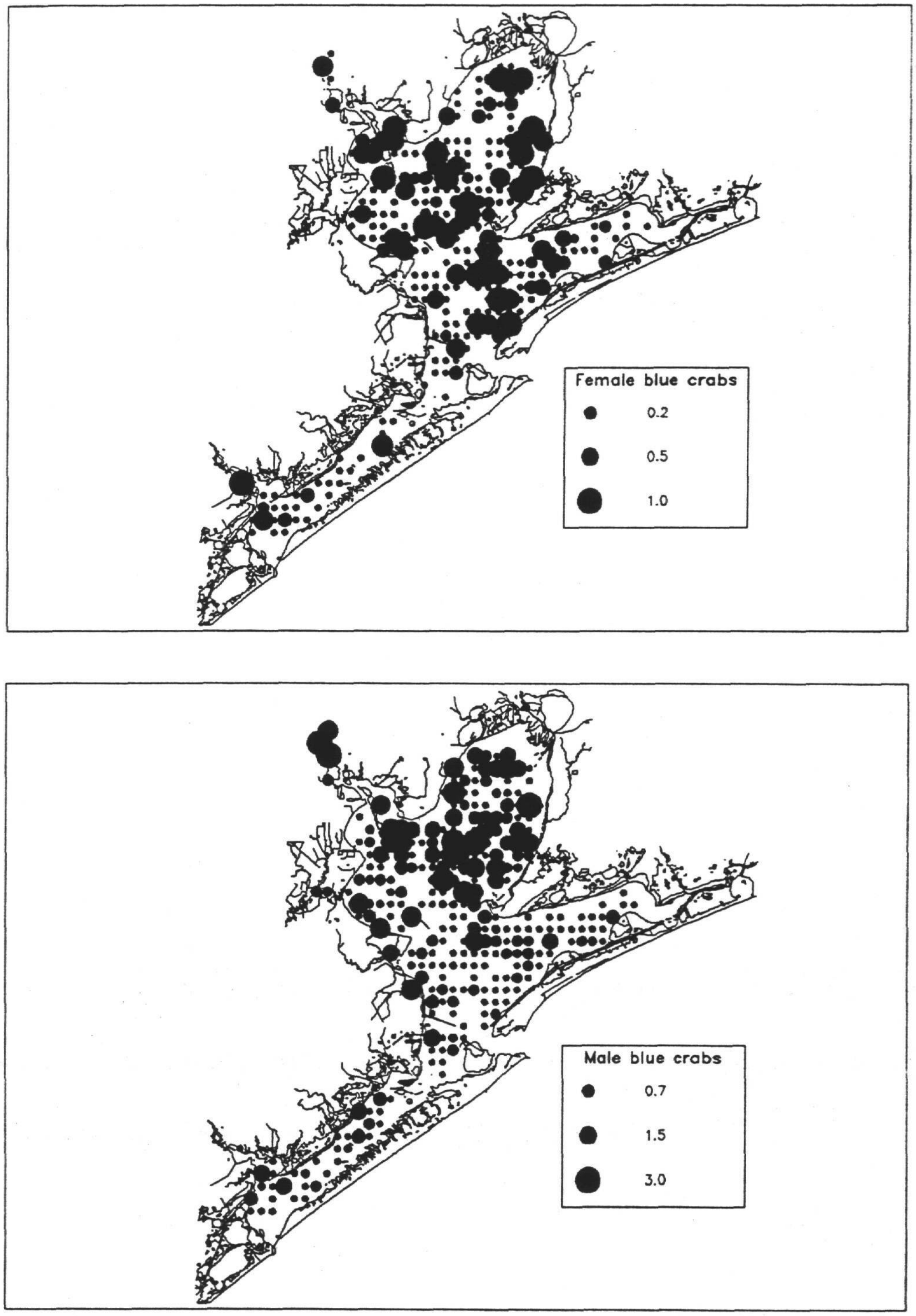


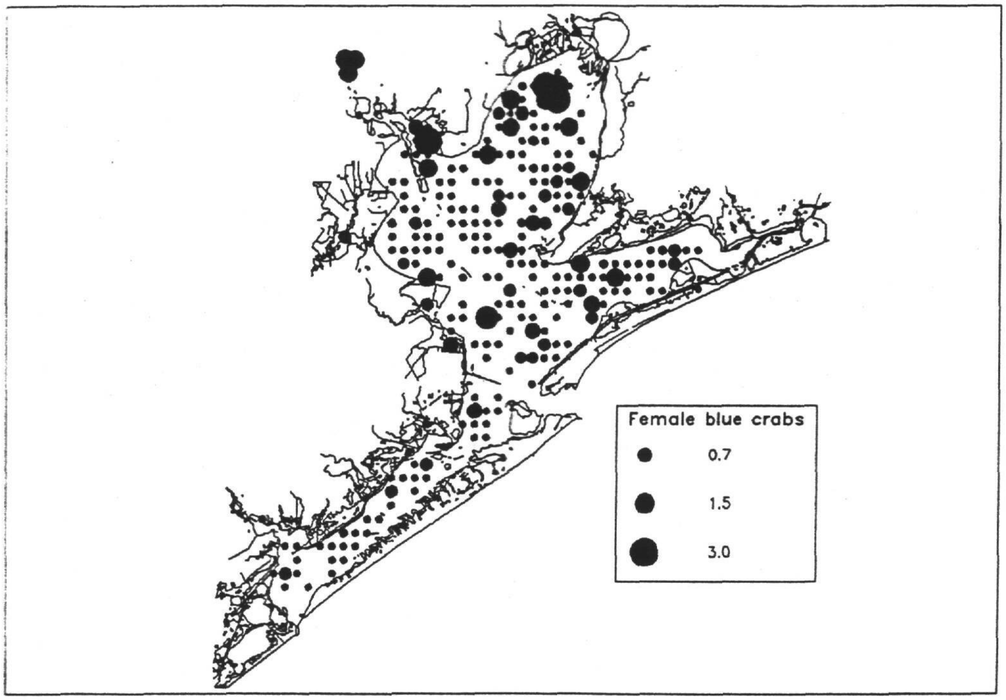
Figure 17. Mean annual CPUE with fitted values and confidence intervals (±S.E.) for blue crab caught by trawl in upper and lower zones of Galveston Estuary. A. Young of the year, 25–45 mm TW, all months. B. Juveniles, 50–70 mm, all months. C. First-time spawners, 120–140 mm, all months.



A

B

Figure 18. Spatial distribution of adult (>120 mm TW) blue crab within the Galveston Estuary, March–July. Trawl data pooled from 1982–1987. Circles size proportional to mean CPUE. A. Females. B. Males.



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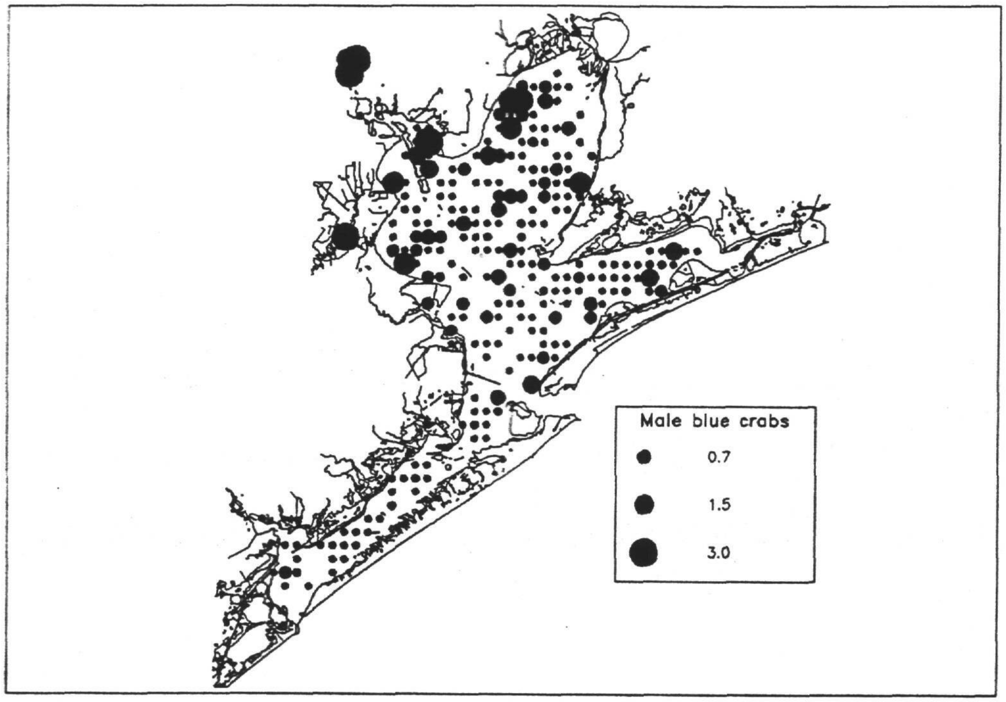
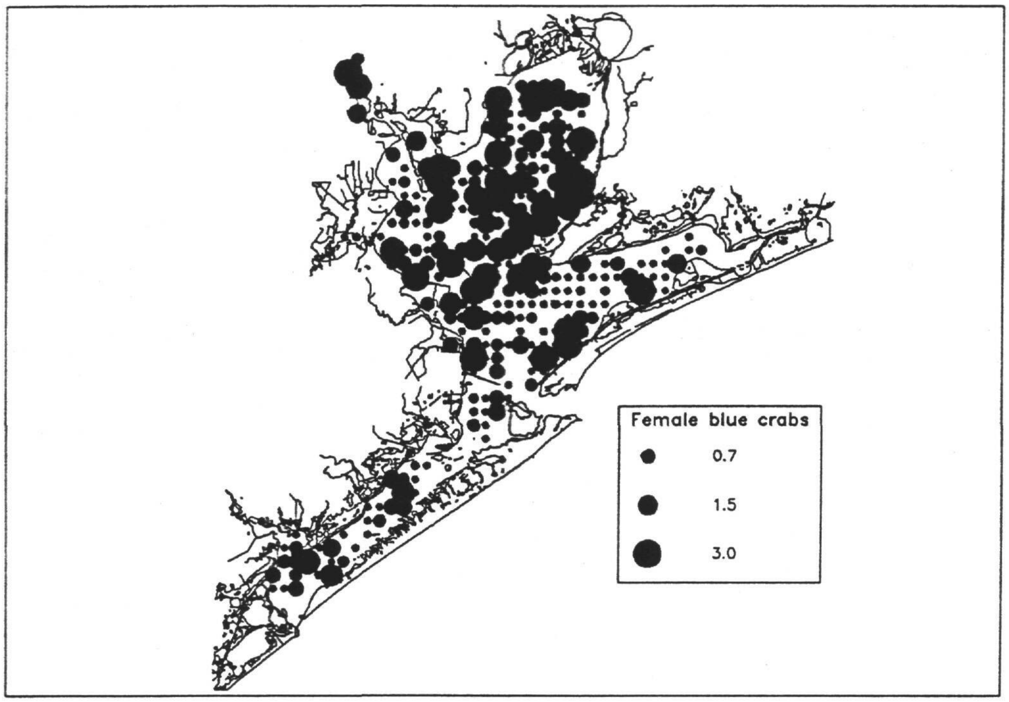
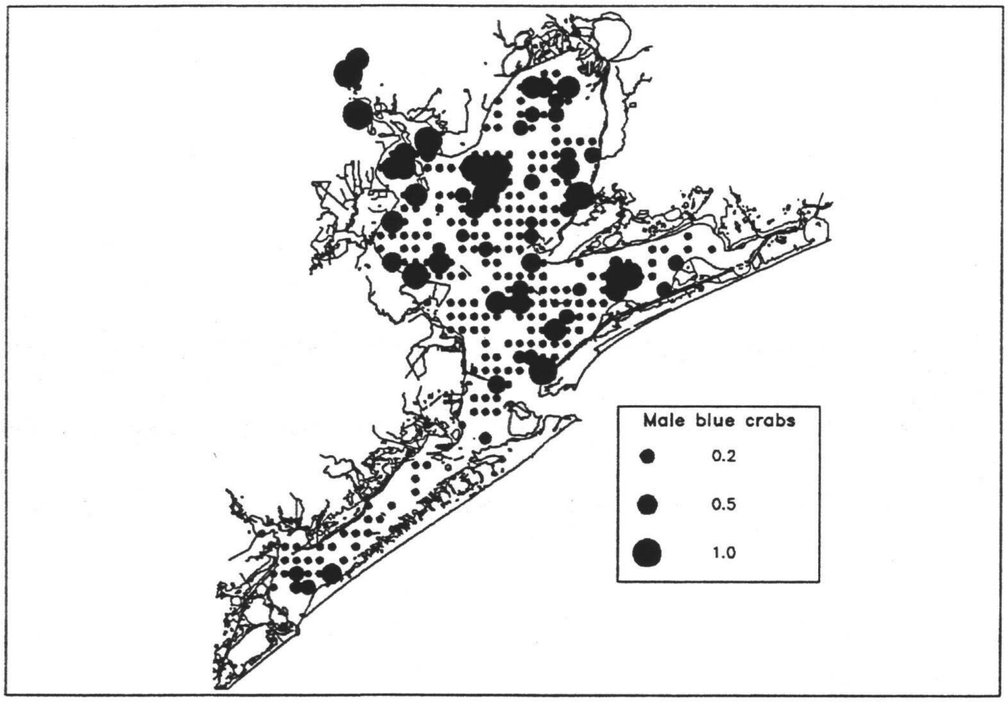


B

Figure 19. Spatial distribution of adult (>120 mm TW) blue crab within the Galveston Estuary, August–October. Trawl data pooled from 1982–1987. Circles size proportional to mean CPUE. A. Females. B. Males.



A



B

Figure 20. Spatial distribution of adult (>120 mm TW) blue crab within the Galveston Estuary, November–February. Trawl data pooled from 1982–1987. Circles size proportional to mean CPUE. A. Females. B. Males.

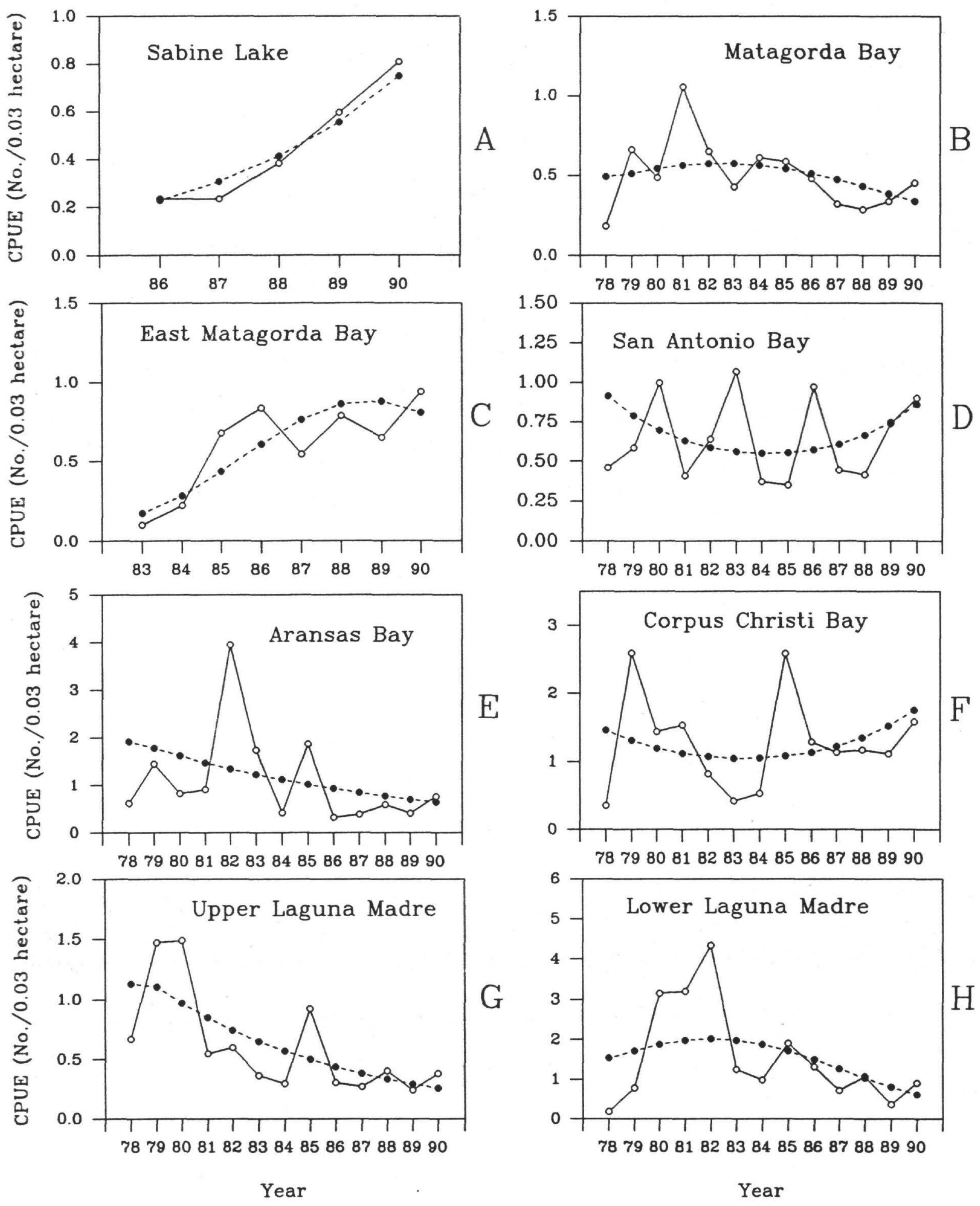


Figure 21. Mean annual CPUE with fitted values for blue crab caught by bag seine, 25–45 mm, all months, in all major Texas estuaries other than Galveston.

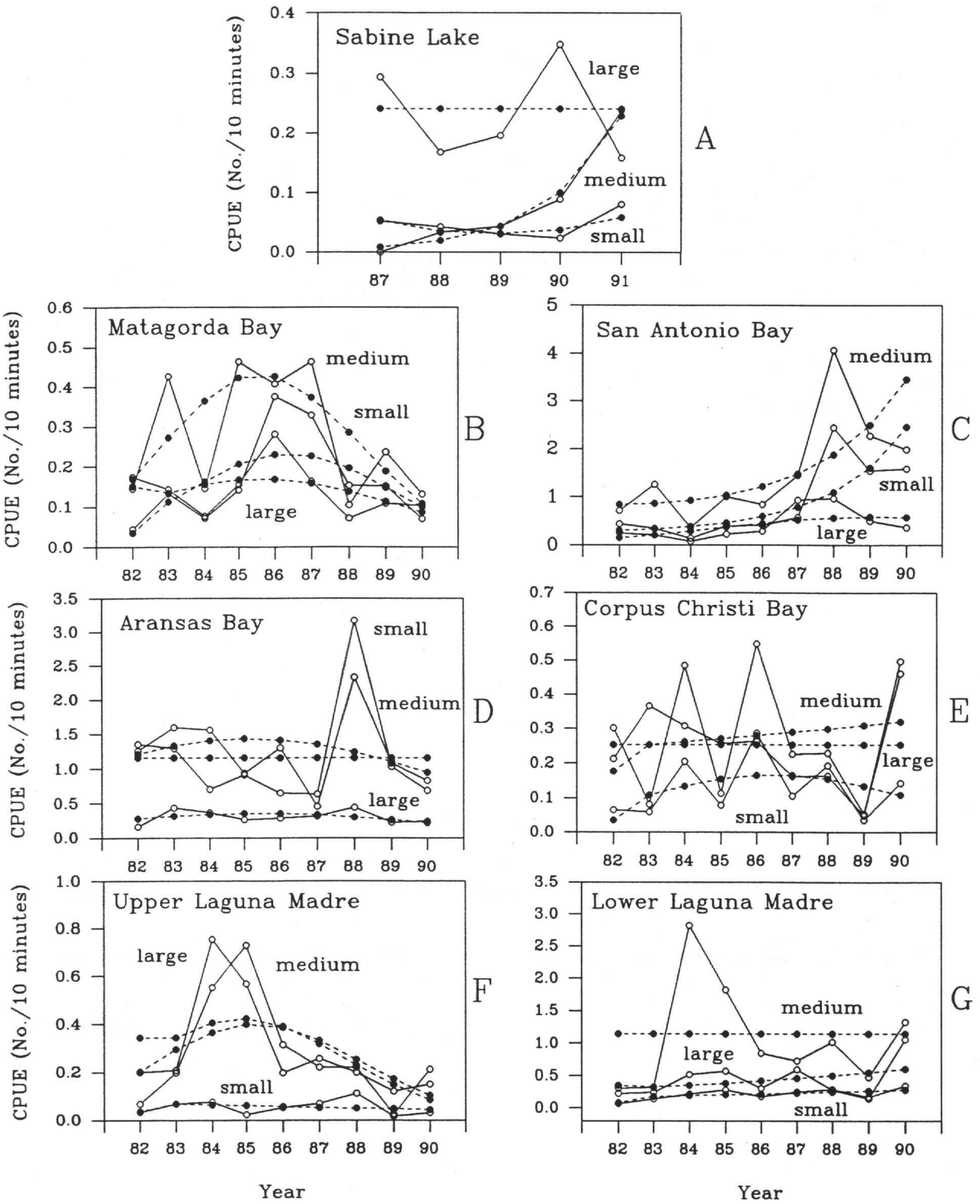


Figure 22. Mean annual CPUE with fitted values for small (25–45 mm TW), medium (50–70 mm), and large (120–140 mm) blue crab caught by trawl, all months, in all major estuaries other than Galveston.

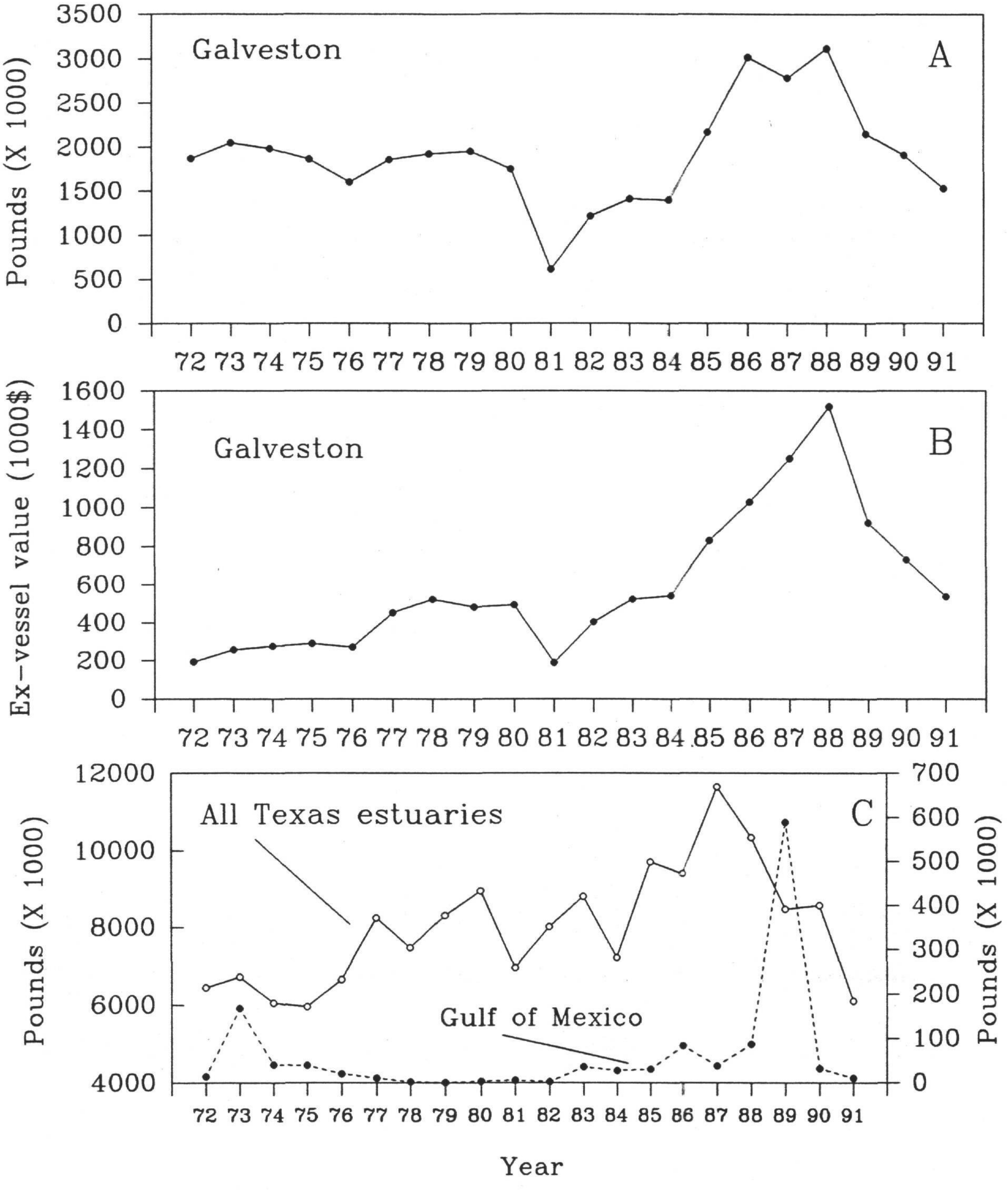


Figure 23. A. Annual commercial landings of blue crab from the Galveston Estuary. B. Ex-vessel value of blue crab landed from the Galveston Estuary. C. Total annual blue crab landings from all Texas estuaries (left axis, hollow circles) and from Gulf of Mexico (right axis, filled circles). Data from Campbell et al. 1992.

Harvest and regulation

Commercial landings of blue crab in the Galveston Estuary increased during the last thirty years (Osborn 1992) as the price of blue crab steadily increased (Figure 23B). Aerial surveys indicate the number of crab traps in Texas bays roughly doubled from 1977-78 to 1985 (Hammerschmidt and Benefield 1986). It requires little capital to enter commercial crabbing relative to other fisheries. Data on recreational or bait crabbing are sparse, though the literature mentions these as important components of the blue crab fishery (Cody et al. 1992). Anecdotal evidence suggests that crab, taken legally and illegally, are popular with visitors and are an important food source for coastal residents. Jaworski (1972) estimated that the actual crab harvest in Louisiana may be twice as high as that indicated by landings records. Perry et al. (1984) also observed that reported commercial landings are probably less accurate than similar data for other fisheries, as a consequence of unrecorded direct sales to fish markets and the public.

Regulations affecting the harvest of blue crab are relatively simple and few: crab traps must be tagged, the number of crab traps is limited per fisherman and in certain areas, gear and gear size are restricted, sponge crabs (egg-bearing females) may not be retained, and crab smaller than five inches (127 mm TW) may not be retained, except for bait. There are no seasons or bag limits and few areas are restricted. Crabs are used as bait mainly by black drum fishermen and account for a very small proportion of the bait fishery; less than 1% of sport-boat fishermen reported using crab for bait during 1983-90 (Cody et al. 1992).

Probable causes

Possible causes for the declines in larger blue crab are listed here in order of confidence and probability. The list is not necessarily comprehensive.

1) **Overfishing**. Overfishing can result from the excessive legal harvesting of adults, excessive black-market harvesting of sublegal-size crab, excessive legal harvesting of juveniles for bait, excessive recreational harvesting (legal and illegal), or ghost fishing (abandoned crab traps).

The bait fishery is probably minor (Cody et al. 1992). Black market crabbing and ghost fishing, though known to occur perhaps extensively, are poorly documented. Data on the recreational harvest are also sparse and estimates of the impact of the recreational fishery vary widely (Cody et al. 1992). Useful data are available only for the commercial harvest of market-size crab, which show that crab are increasingly valuable and exploited with increasing intensity coastwide (Figure 23C). Market-size populations of blue crab may be declining in step.

Given that larger blue crab (>60 mm) are cannibalistic on small blue crab, the number of juveniles may be increasing as their predators decline (discussed below). It is also possible that the harvest of market-size blue crab is sufficiently intense to impose selection for small size, as has been proposed for other fisheries (Nelson and Soulé 1987).

2) **Natural (non-human) predation**. Many of the same predators that consume white shrimp also eat blue crab: Atlantic croaker (Figures 1C, 2B, 14A), southern flounder (Figures 1V, 14D), spot (Figures 1G, 2E), red drum (Figures 1R, 14E, 14F), spotted seatrout (Figures 1T, 14G, 14H), black drum (Figures 1W, 14C) and pinfish (Figures 1K, 14B; Matlock and Garcia 1983, Millikin and Williams 1984, Thomas et al. 1990, Steele and Perry 1990). Other predators include raccoons, birds (clapper rail, great blue heron, and mergansers), and larger blue crab (Darnell 1958, Millikin and Williams 1984, Steele and Perry 1990).

Pinfish, spot, spotted seatrout, red drum, and black drum increased in population in recent years. Predation on small blue crab by fish probably increased, though predation on small crab by larger blue crab probably decreased. How this natural predation compared to the harvest by humans or other human-induced factors is unknown.

3) **Natural cycles** and natural environmental effects. The time series is not long enough to demonstrate a periodicity greater than two or three years. Though many environmental variables are known to affect blue crab (e.g. temperature, salinity, wind direction at the time of megalopal migration into the estuary), most short-term events have only short-term or local effects. Low harvests and low bag seine catches in 1981 probably resulted from low recruitment that year, but did not affect the overall trend. Available climatic data (Chapter III) show little correspondence with blue crab CPUE data.

4) **Variation in freshwater inflow**. Blue crab thrive at low salinities and occur in greatest numbers in estuaries receiving substantial fresh water inflow (More 1969). However, salt water is a limiting factor because a salinity near that of sea water is a physiological requirement for spawning (More 1969). Records of river inflow to the Galveston Estuary (Figures 3B, 3C) suggest a possible relationship between inflow and blue crab recruitment, in that low trawl catches of blue crab during 1988 may be related to a dry year (associated with a La Niña event). However, the decline in the largest sizes of blue crab continued in spite of high inflows during 1989-1991.

5) **Increased morbidity** (disease and parasites). Blue crab pathologies are relatively well-documented (Millikin and Williams 1984), though their incidence in the Galveston Estuary is not. The CF data set records observations of infestation by <u>Loxothylacus texanus</u> (a sacculinid barnacle) only from 1982 through 1987. There is no obvious trend (Figure 24). Anecdotal evidence (McTigue, pers. comm.; Wardle, pers. comm.) suggests sacculinid infections are localized, and the rate of infection may be reduced in 1991-1992 as a consequence of high freshwater inflows (Ragan and Matherne 1974). Though crab morbidity may be a factor in observed population trends, the available data do not show it.

6) **Loss of wetland habitat and SAV**. Wetlands, especially submerged aquatic vegetation, are heavily used by juvenile blue crab (Orth and van Montfrans 1990).

Wetland loss has undoubtedly affected blue crab, though the most rapid loss of vegetated wetlands in the Galveston Estuary (discussed in Chapter IV) occurred mostly before the period of CF sampling. Wetland loss alone does not explain the pattern of trends in various size classes because juveniles show an increase at the same time that adults, which use vegetated wetlands less intensely, declined.

7) Mortality or habitat disturbance caused by **shrimp trawling**. Blue crab are one of the most common species captured by trawling (Figure 2C) and a well-documented "bycatch species" (Bryan et al. 1982, Nance et al. 1993). Blue crab are also one of the species most likely to survive being trawled, exposed to air, and discarded, by virtue of their hard carapace and resistance to dehydration. Other "bycatch species" (Nance et al. 1993) include Atlantic croaker (Figure 2B), Gulf menhaden (Figure 2F), sand seatrout (Figure 2G), bay anchovy (Figure 2M), spot (Figure 2F), and brief squid (Figure 2J), of which only squid show a possible decline. Though direct mortality caused by shrimp trawling is likely to affect other species before blue crab, the possible role of habitat disturbance is unknown.

8) **Water quality**. Blue crab are "hard to kill" and adaptable to a variety of habitats relative to other species. Pollution is more likely to affect other species before blue crab, because the crab hepatopancreas is effective at removing common toxins (Millikin and Williams 1984). The study of toxic contamination in food organisms by Brooks et al. (1992) found blue crab to be less contaminated than oysters, spotted seatrout, black drum, or southern flounder.

9) **Change in forage base**. A food supply problem would similarly appear in other species before blue crab, which are classified as detritivores, omnivores, or opportunistic carnivores depending on ontogenetic stage or food availability. Large blue crab are relatively unspecialized carnivores that consume a variety of fish, crustaceans, mollusks, and annelids (Perry et al. 1984, Alexander 1986, Steele and Perry 1990, Fitz and Wiegert 1991).

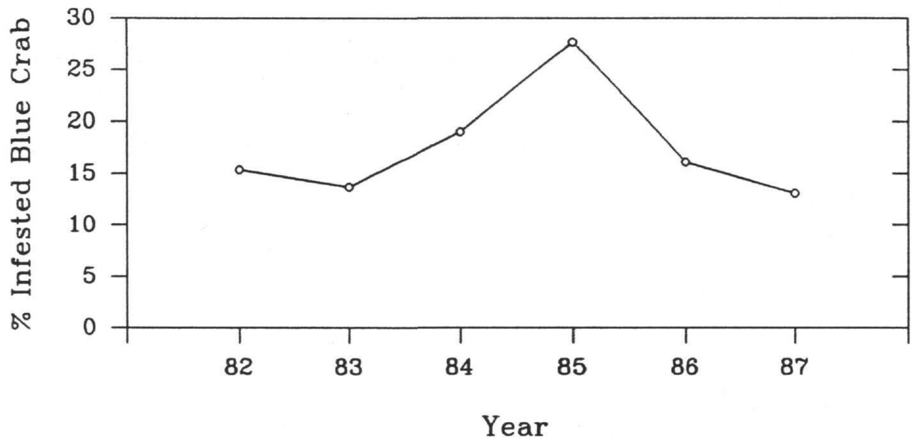


Figure 24. Annual percentage of blue crab in trawl samples parasitized by *L. texanus* (out of all crab typed).

Discussion and conclusions

The data presently available suggest directed growth overfishing to be the greatest influence on observed blue crab population trends. This conclusion is qualitative, however, because blue crab are exceptionally complicated among fisheries species. Their life cycle is complex, there is a surprising number of unanswered questions about blue crab biology for such a ubiquitous species, and the many aspects of the harvest are relatively poorly documented.

A separate, but possibly related, question from the decline in market-size adults is the apparent increase in intermediate-size blue crab in bag seine catches (Figure 15) associated with decreases in the same size classes in trawl catches (Figure 16). Bay margin habitat may be increasingly favored relative to open-bay habitat because of spatial shifts in food supply. As an alternative explanation, an increase in mortality among large blue crab (probably human-induced) may result in decreased mortality (by cannibalism) and increased availability of resources (by reduced competition) for the smaller size classes.

The study of ambient water quality in Galveston Bay by Ward and Armstrong (1992) shows a decline in total suspended solids (TSS; turbidity), nitrates, and chlorophyll a over the past thirty years. As discussed in Chapter IV, these trends probably demonstrate that regulation of industry has been successful in reducing nutrient loading (Stanley 1989). In light of the trends in blue crab, they may also indicate a slow decline in primary productivity in mid-bay regions while bay margins remain relatively productive. Zimmerman et al. (1991) suggested that drowning coastal marsh is even more productive than stable marsh, so young blue crab may be taking advantage of the temporary benefits of relative sea level rise. The long-term effects of declining TSS are unknown. Drowning marsh will eventually be replaced by open-bay bottom, with unknown, but probably unfavorable, consequences for blue crab.

A continued decline in large blue crab will eventually lead to a collapse of the commercial fishery in the Galveston Estuary and probably an intensification of crabbing pressure elsewhere. The ecological consequences of a reduction or disappearance of large blue crab are the subject of speculation. Small blue crab are probably more heavily preyed upon than large blue crab, so continued high recruitment would probably ensure the presence of an important food item for many species of fish and birds. However, a severe decline in adult blue crab would probably affect recruitment eventually, especially if the declines extend beyond the Galveston Estuary. There are probably food items that are only available to predation or scavenging by crab of some minimum size, but the possible effects of the absence of the predator or scavenger are unknown.